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# Physical Modeling of Flow around the Underwater Tidal Power

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**Abstract**

The flow near the underwater tidal power with orthogonal vertical hydro turbines is studied. The flow is modeled using the particle image velocimetry (PIV). The series of experiments study the flow near the model. In the experiments flow is approximated by the two-dimensional problem; this approximation is related to the shape of the power, a characteristic linear dimension greater length relative to other sizes. According to the results of post processing experiments instantaneous velocity vector fields were obtained, then they were transformed into the time-averaged velocity field and streamlines


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*Keywords:* PIV technique; underwater tidal power; aerodynamics; flow visualization; velocity field; the line current.

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## 1. Introduction

This paper investigates the flow near the underwater tidal power orthogonal vertical hydro turbines.

In Russia and the world at large continues unabated interest in tidal power projects. Rising prices for fossil fuels, depletion of their reserves, environmental concerns, push development projects on the use of tidal energy in the actual discharge [1].

Challenges inherent to tidal power projects, such as the high cost structures, large volumes of construction work, the need to compensate for uneven energy output, need to be addressed and resolved with the improvement of equipment, working procedures, technology, manufacture of building structures and materials.

The main task of tidal power projects is to increase economic performance and competitiveness with alternative energy sources. A large role is played here by the main power equipment [2]. In recent years, modeling and field testing of the orthogonal turbine are researched. Orthogonal hydraulic turbine installation on the tidal power has several advantages; relative simplicity of design, the savings in terms of concrete, weight and cost of the turbine equipment; the same energy performance in the opposite direction of flow; higher throughput when stopped turbine eliminates the special culvert dam construction work in bypass mode.

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Orthogonal turbine at tidal powers is new equipment. Study of the specific features of this equipment, optimization of its operation under the tidal power compensation issues, when working as part of the energy complex seems urgent problem, the solution of which is devoted to this work.

At this stage of experimental aerodynamics, wide application of computer technology in conducting physical experiments is used. One of the methods requiring the use of a high level of computer technology is a method of digital flow visualization (Particle image velocimetry (PIV)) [3,11]. Therefore, only in recent years, this method began to flourish. At the moment it is one of the most advanced in the field of physical modeling, as it allows non-contact measuring and visualization of the vector velocity field for the three components in the selected section of fluid flow [4-11].

## 2. Methodology

The principle features of this method are monitoring and correlation processing of the reflected light from the flow placed in special particles. That is, the moving stream of liquid seeded with small particles is illuminated by plane laser knife. Tracers movement recorded by high-speed digital matrix cameras CMOS (Complementary Metal-Oxide Semiconductor). Next, a series of images are processed using the cross-correlation method.

In the experiment, the configuration applies PIV type Flow Master High-Speed (Time Resolved), which includes the following components: a double pulse laser series LPY 700; power supply and laser cooling LPU 550; Optical Systems and Laser Guiding Arm Sheet Optics (divergent); synchronization unit High Speed Controller; two high-speed cameras Imager Pr oHS4M; System Linear Translation Unit; PC software LaVision DaVis.

For air stream flowing over model an aerodynamic installation AeroLab is used in the model area, which housed the model investigated

We will consider the flow near the underwater tidal power orthogonal vertical hydro turbines. In the experiments flow is approximated by the two-dimensional problem, this approximation is related to the shape of the power, a characteristic linear dimension is of greater length relative to other sizes.

To identify and further study the two-dimensional flow near underwater tidal power a series of experiments has been made, during which the model was used (figure 1).

Fig. 1.Model of underwater tidal power orthogonal vertical hydro turbines.

General view of the model is shown in figure 2. Uncertainty in geometrical dimensions is less than 0.5 mm. Height of the model is 80mm, width – 84mm, length – 305mm. Size of the top row of holes is 15x22mm, of low row – 15x19mm. The distance between the two holes of a row is equal to 7 mm, between rows - 5 mm. The model is made of a wooden beam with an inset of the plywood 5mm thick. Model impregnated moisture barrier composition, covered with black matte paint.

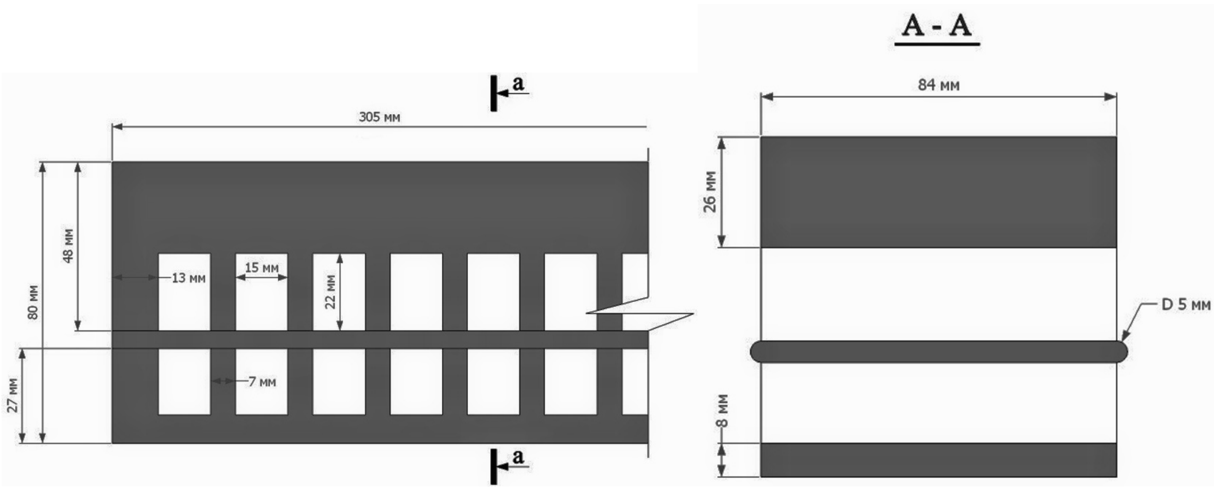


Fig. 2.The typical dimensions of the test model.

During conducting a physical experiment the nature of the plane flow stream flowing over the model has been determined, the velocity of which was 9 m/s. The model was placed in the model area, whose dimensions are 305x305x600mm. The length of the model coincide with the width of model area, that is, its edge in contact with the opposite walls of the model area. The study plane is situated in the central cross section plane of the model and the model area, respectively, its axis coordinate y is 152.5 mm. The study plane passes through the center of the hole simulating channel for orthogonal vertical hydraulic turbines.

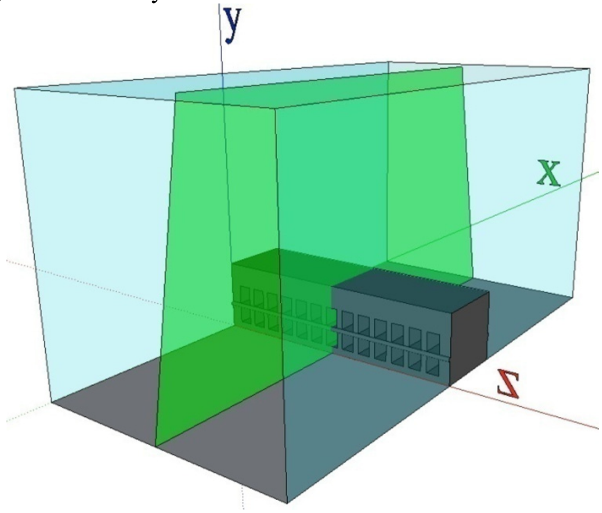


Fig. 3.Location of the model in the area of the laser sheet illuminating the study plane.

To exclude shady areas during shooting the study plane was divided into two parts: the first is in front of the model, the second is the area behind it.

As a result of a series of experiments for each experiment was obtained a succession of images in a pairwise shooting (doubleframe) with the time between two frames 200 ms, the frequency between the two pairs of frames was 15 Hz. The number of shots was 200 pieces. The resulting series of images were used for further processing of the cross-correlation. Multipass algorithm works was used. During the first step, the rendering area with a rectangular cross section and an area 128x128 pixels with 75% overlap were used, the number of passes was two. At the second step, the cross-section area calculation with adaptive forms area 64x64 pixels with 50% overlap were used, the number of passes was two.

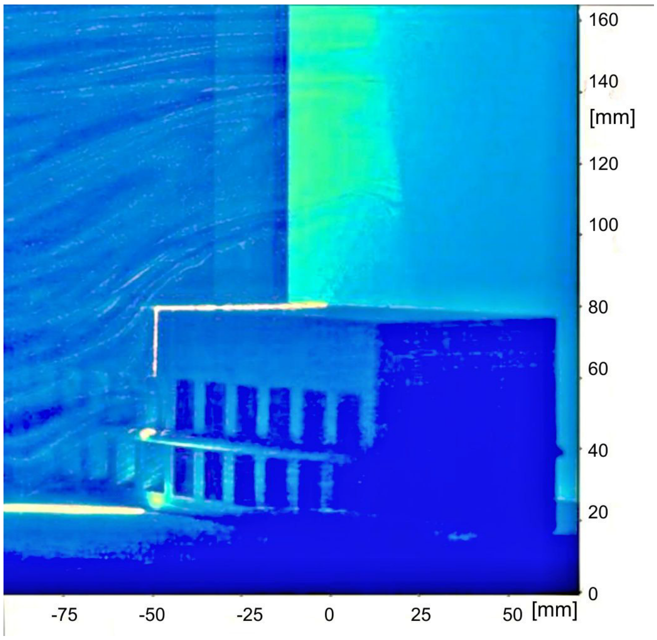


Fig. 4. Example of images obtained during the experiment using PIV method.

According to the results of postprocessing some experiments instantaneous velocity vector fields were obtained, then they were transformed into the time-averaged velocity fields and streamlines. For averaging the instantaneous velocity vector fields was used formula(1):

$$V_{Xcp} = \frac{1}{n}\sum_{i=1}^{n} V_{Xi}\ ; \quad V_{Ycp} = \frac{1}{n}\sum_{i=1}^{n} V_{Yi} \tag{1}$$

where: $V_{Xcp}$– averaged velocity along the $X$ axis; $V_{Ycp}$–averaged velocity along the $Y$ axis; $V_{Xi}$–instantaneous velocity along the $X$ axis; $V_{Yi}$–instantaneous velocity along the $Y$ axis.

The experimental results are instantaneous and averaged velocity field. Publication of all results in this paper is not possible. Therefore, in Figures 5-6 are presented only averaged flow streamlines.

In the first region, situated in front of a model the change of the incident flow pattern caused by the influence was studied. We can sees lowing of the flow over the model and a change in direction in the lower region. Stream is divided into three parts, the main wraps around the top model, the remaining parts of the model tested through the channels. On the model of underwater a tidal power characteristic is observed during the high speed. Flow velocity and direction at the boundary layer, as well as in models of channels, is not set because of the peculiarities of the measuring system and its configuration in this series of experiments.

For the second area, located at the back of the model, the turbulent wake and vortex formation in the flow region were investigated. This zone has highly turbulent component and instability in the formations, so the average velocity field is not in the whole area; to show a vivid pictures and for their analysis it is necessary to resort to the instantaneous velocity fields. Consider the flow pattern shown in figure6. From the influence of the flow front and rear edge a vortex is formed by model. Under this additional vortex one more vortex is formed from the merger of the swirling flow of the upper vortex and jet outlet of the channel model. Part of the flow channel from the top and from the bottom are joined. A small part of the lower flow channel formed weak vortex in the bottom corner.

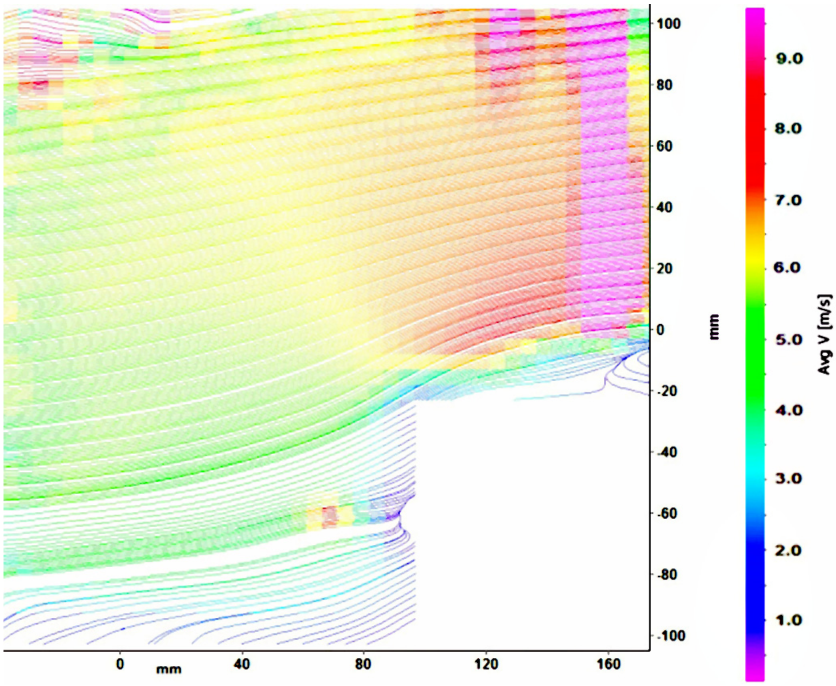


Fig. 5.Averaged flow streamlines in the first region.

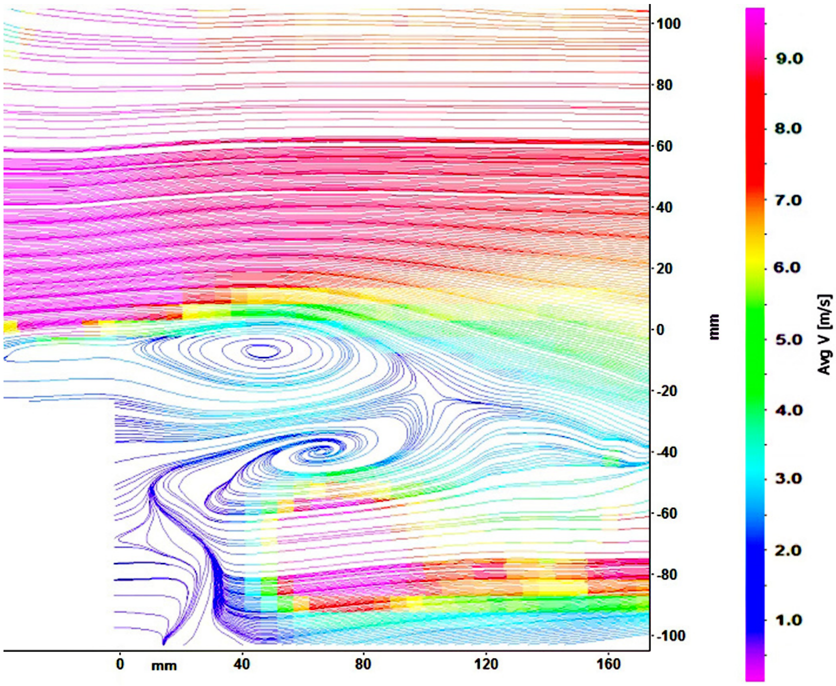


Fig. 6.Averaged flow streamlines in the second region.

## 3. Conclusion

In Russia and the world at large continues unabated interest in tidal power projects. Rising prices for fossil fuels, depletion of their reserves, environmental concerns push development projects on the use of tidal energy in the actual discharge [1].

Orthogonal turbines are new equipment having specific characteristics that require research water and energy regimes.

At the moment, the PIV is one of the most advanced in the field of physical modeling, as it allows non-contact measuring and visualization of the vector velocity field for the three components in the selected section of fluid flow.

The series of experiments represent the picture flow model of underwater tidal power orthogonal vertical hydro turbines. In the experiments the flow was approximated by the two-dimensional problem, this approximation is related to the shape of the power, a characteristic linear dimension of a greater length relative to other sizes. These experiments show features paintings of the flow model, having channels for placement of water turbines from the flow pattern of a rectangular prism, which gives an idea about the real flows around the underwater tidal power. Given the use of the simplified model and other media, which was implemented in this series of experiments; we can assume the existence of errors in the absolute values of the velocity.

For more reliable results in the preparation of these values more research are needed, which means specification of the model and change of the medium of flow.

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